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FACTORS GOVERNING THE SELECTION AND PROTECTION OF SOURCES OF WATER SUPPLY

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FACTORS GOVERNING THE SELECTION AND PROTECTION OF SOURCES OF WATER SUPPLY.

A wholesome, ample, and satisfactory supply of water is one of the fundamental needs of any community, regardless of its size, and, therefore, the selection of the source of a supply having these qualities is a problem that has been solved or must be solved by every group of individuals forming a community, regardless of whether this group be the isolated family or the large city. The degree of success attained in the handling of this problem is quite closely related to the comfort, well being, and health of the community.

There are certain factors that must be taken into consideration in the selection of a suitable source of water supply, and these various factors must be carefully weighed in the light of local requirements in order that that source may be chosen which most nearly meets the local needs. No absolute rules can be laid down for universal adoption, but general principles can be stated which, through long experience, have been found to be of value in reaching a wise decision. The following are some of the factors that must be considered: the nature and extent of use of the contemplated supply; the sources available; the quantity of water available; the quality of available supplies; the possibilities of pollution of the supply; the natural safeguards that may be employed for protecting the supply; and the cost of installation and operation of the system.

Nature and Extent of Use.

The nature and extent of use of a contemplated water supply will often determine the choice of a source. If water is to be used for industrial purposes, such as boiler feed water or for the washing of white paper stock, evidently the qualities required would be different from those necessary in a water used for cooling or condensing purposes or for fire protection. If the supply is to be used for drinking and other domestic purposes, then other qualities are requisite, such as freedom from disease organisms, qualities not essential to a strictly industrial supply.

For obvious reasons the extent of use must be known. A small mountain stream might readily supply a village but be entirely inadequate for a growing city; or a well might be of ample capacity for one industry but totally unable to supply a community. The ultimate yield of any prospective source must always be considered and reasonable assurance obtained that it will always exceed the maximum anticipated demand.

Sources of Supply.

After the nature and extent of use are determined, the selection of a source will evidently be somewhat restricted. It may be well, therefore, to discuss the various sources of water so that all available supplies may be given consideration.

Primarily, all available water is of meteoric origin. Water is evaporated from the ocean and surface of the earth, is condensed and falls as rain, and then flows, either on the surface or underground, from higher to lower levels until the ocean is again reached, thus completing the cycle. It is therefore necessary to obtain a supply from some source within this cycle. Since the collection of falling rain water is expensive and difficult, although often resorted to by individual families, the remaining sources, surface and underground waters, are usually those generally considered.

Collection of rain water is usually feasible only for restricted use, such as for individual families, because of the necessary surface required for such collection. Roofs are the most common collecting surface used, and the water draining therefrom is stored in various ways. Such storage should not be exposed to light because of the rapid development, under such conditions, of various organisms and plant life that will impart disagreeable odors and tastes to the stored water.

Surface water may be secured either from flowing streams or from natural lakes. Water may be pumped directly from streams or it may be diverted into impounding or storage reservoirs and drawn from them. Lakes are usually of the nature of natural impounding reservoirs, and supplies of water are frequently drawn directly from them. Owing to the necessary contact with the surface of the earth and the existing polluting conditions thus encountered, surface waters contain varying amounts of dissolved and suspended foreign matters that often render the supply objectionable and even unsafe.

That portion of the rain water falling on the earth that percolates through the surface layers and fills the interstices of the porous material encountered, is referred to as underground water. Owing to the close contact of such waters with the earth, ground waters frequently carry in solution considerable quantities of mineral substances, such as iron, salt, sulphur, limestone, etc. Ground waters may be collected by means of wells reaching into the submerged strata, by springs, or by horizontal or inclined collecting galleries channeled or driven so as to intercept or divert the natural underground flow.

Wells are of three general types: shallow, deep, and artesian. Shallow wells are what the name implies and draw their supply from ground-water storage of the surface earth layers. They are therefore frequently subject to gross contamination, and for this reason their use for domestic supply in urban communities is usually prohibited.

Deep wells are those reaching to the deeper water-bearing strata of the earth, thus drawing water from the truly underground sources of ground-water storage. Surface water is usually excluded from such wells by means of water-tight casings or linings extending from above the surface downward to the underground water-bearing stratum that furnishes the supply. Deep wells are driven, bored, or drilled, depending on whether the casings have been driven through soft strata, by means of blows, or bored through clay and similar easily penetrable material by means of augers, or drilled where harder strata are encountered. In some cases all three methods may have been employed on the same well.

Artesian wells are those that flow, owing to underground hydrostatic pressure. This pressure is usually developed by a warped, porous, water-bearing stratum being inclosed between two impervious layers, and receiving its water at a higher elevation than that of the ground surface at the point tapped by the well. Deep, nonflowing wells are frequently but incorrectly termed artesian wells.

Owing to the force of gravity, underground waters, unless impeded, are in continuous motion. Because of various geological formations of impervious materials, the underground flow may be forced to the surface and form a spring. Such springs frequently exist in hilly country with underlying rock formations; they are oftentimes of considerable volume and may thus furnish suitable sources of water supply. Springs frequently form the sources of surface streams or emerge along stream channels, thus becoming a part of the surface supply.

Infiltration galleries are usually tunnels, collecting pipes, or chambers constructed across the underground flow channels in such a manner as to divert the normal course of the underground water to central collecting points from which it may be taken as desired. The most advantageous locations for such works are generally at low points along the base of inclined impervious strata upon which pervious water-bearing strata are superimposed. Infiltration cribs have frequently been placed along stream channels, below the water surface, thereby drawing part of the supply from underground sources and part from the surface supply of the stream. Owing to the uncertainty of the quality of water thus obtained, it is inadvisable to use such a source unless further treatment is contemplated.

Quantity of Water Available.

An important factor in selecting a source of water supply is that of sufficient quantity from the contemplated source. In reaching a proper determination on this question, capable engineering advice should be sought, for varying factors exert a most important rôle in the yield of different watersheds. Moreover, the determination of

the probable maximum demand of water requires careful study. It should be borne in mind, however, that the amount of rainfall is always the maximum limit of available supply. Hence the volume and distribution of rainfall, the size of the catchment area, and the percentage of the rainfall that is actually available are functions of the yield that may be expected from any source. Each of these factors can be further analyzed into its component parts so that an intelligent estimate can be formed of the weight or value of the whole. Thus, in the matter of a surface supply, the percentage of the rainfall actually running off is altered by such conditions as permeability of the top soil, evaporation, transpiration, temperature, and other factors.

In estimating the yield to be expected from underground sources, still other conditions must be given consideration. The nature, extent, and position of the various geological formations largely determine the volume of underground water available in any region as well as the quality of the supply. A considerable knowledge of the geology of a region is therefore required if one is to judge competently the extent of an underground source of water.

In many cases the total amount of surface water available from a given source is ample, but owing to various conditions the rate of run-off may be exceedingly variable and hence at certain seasons be entirely inadequate. To tide over such dry periods, impounding or storage reservoirs may be necessary in order to retain part of the excess flow during the wet season and release it when needed. Many instances of such equalization systems are in operation.

The problem of securing a suitable quantity of water is therefore very frequently an engineering problem that requires considerable study and experience for its proper solution, and no such problem should be undertaken without the assistance of competent engineering advice.

Quality of Water.

In the selection of a source of water supply, quality is a prime requisite, and this fact must be kept clearly in view. If a supply is deficient in quality, it can never reach the degree of usefulness that consumers have a right to demand regardless of the many other points it may have in its favor. There are numerous characteristics that determine the quality of a supply, but in general they may be grouped under three heads: (1) sanitary quality, (2) chemical quality, and (3) physical characteristics.

1. SANITARY QUALITY.

The sanitary quality of a water has to do with its relative freedom from pathogenic organisms or those which cause disease or otherwise affect the health of persons drinking it. The most common disease

organisms transmitted by water are those of typhoid fever, dysentery, and cholera, which diseases, because of this common mode of transmission, are frequently termed water-borne diseases. In some waters there are other forms of organic life present, organisms whose action is not definitely known but which are certainly not beneficial and may even be detrimental to health. To be of satisfactory quality, a drinking water must be practically free of pathogenic organisms, and the standards are being constantly increased to the point where practical freedom from all organic life may soon be required.

For ascertaining the sanitary quality of a water, carefully standardized methods have been developed which permit the making of detailed comparisons; and complete information should be had, in the light of these procedures, in regard to any contemplated source. These methods relate, in brief, to the bacteriological analysis and to the sanitary survey of the watershed. One bacteriological analysis is of comparatively little value, but a series of such analyses, covering a considerable period of time and taken under a variety of conditions, gives a valuable index of the sanitary quality of the water. Such analyses, combined with a carefully made sanitary survey of the watershed with a view to locating and weighing the importance of all existing sources of pollution, will produce valuable evidence from which safe decisions may be made.

It is not the intention to discuss here the details of bacteriological technique of water analysis—water analysis has become a highly developed and well standardized science—but a few remarks on the broad features of its foundation may be of value in explaining its applicability to the question under discussion.

No practicable method has yet been devised to isolate the typhoid organism from water. Moreover, it has been done so rarely that the procedure is of no significance. It is entirely practicable, however, to isolate and enumerate a group of organisms similar in many respects to the typhoid bacillus, and one whose natural habitat is the same as that of the typhoid organism, namely, the intestinal tract of human beings, and hence always present where typhoid organisms are found. This group, called *Bacillus coli*, is therefore in reality a more sensitive index than the typhoid organism itself; for while the latter would be found only where typhoid bacteria were actually present, the presence of *B. coli* is indicative of excremental pollution, either animal or human, which may or may not be of a dangerous nature, since the *B. coli* group itself is nonpathogenic.

The permissible extent of occurrence of *B. coli* in a water supply has been a much discussed question, and the fixing of any standard of this nature is difficult. The Treasury Department of the Federal Government, responsible for the sanitary quality of drinking water on interstate carriers, has set a bacteriological standard for such

supplies that is admittedly high.[1] Briefly, this standard requires that the total bacteria developing on agar plates in 24 hours at 37° C. be less than 100 per c.c. of the sample and that not more than one of five 10-c.c. portions of a specimen shall contain *B. coli* when examined by the standard procedure.

Bacteriological examination should not be the sole means of gauging the sanitary quality of a water supply, however, but should be made in connection with a thorough inspection of every part of the area with which the water may come in contact. All possible sources of continuous, intermittent, or accidental pollution should be examined and noted in order to estimate the real or potential influence of each such source on the sanitary quality of the water. The nature and extent of such possible sources of pollution will largely influence the methods to be inaugurated for the protection of the supply. Such surveys should be repeated at frequent intervals in order that detailed information may be complete and up to-date. The sanitary quality of any supply is the most important factor to be considered, because even a temporary or periodic lapse of precaution may exact a toll of human lives from water-borne diseases. Consequently too much care can not be taken to prevent such occurrences.

CHEMICAL QUALITY.

While the chemical impurities found in water are not generally so detrimental to health as bacterial pollution, yet, from an economic standpoint, such impurities are often of such a nature as to demand careful consideration. Water in passing over or through certain mineral deposits, dissolves small amounts of these substances and carries them off in solution. Ground waters, because of the generally longer and more intimate contact with the earth, are, as a rule, more heavily impregnated than surface waters. The mineral content of ground waters is naturally closely related to the geology of the region from which they are obtained. The chemical features most ordinarily encountered are hardness, miscellaneous mineral content, and gases in solution.

Hardness in water is usually caused by the presence of salts of calcium and magnesium in the form of either sulphates or carbonates. These salts render the water objectionable for household purposes and some industrial uses because the calcium and magnesium unite with soap to form insoluble compounds, causing unsightly scums and precipitates, and thus render the soap ineffective. The added cost for soap in a community where hard water is used is greater than generally supposed. Whipple states (1, p. 26) that it requires 1 pound of average soap to soften 24 gallons of water having a hardness

[1] Interstate Quarantine Regulations of the United States. Misc. Publication No. 7., United States Public Health Service, Washington, D. C., 1916. Page 40

of 200 parts per million; or in other words, before a lather can be produced, a pound of soap is consumed in 24 gallons of such water.

Hardness is objectionable for many industrial purposes also, because of the deleterious chemical actions produced. Thus in dye and dyeing industries, sugar refining, textile trades, tanning, paper making, etc., soft water is necessary. Used in boilers, hard water forms a scale or incrustation on the inner surfaces and greatly reduces the efficiency for steaming purposes, because of the low heat conductivity of the scale. Excessive scale even causes the metal tubes to burn out, resulting in the expense of replacement. Wherever possible, therefore, hard water should be avoided as a source of supply.

Water frequently contains other mineral substances that are objectionable; iron, manganese, and chlorides being among the number. Iron and manganese form red precipitates and stains and may affect the taste of the water as well. They can generally be removed by treatment processes such as aeration and precipitation. Many well supplies, especially along the salt-water coasts have a high chloride content which, on excessive pumping, tends to become even higher. The abandonment of such supplies is generally the only feasible remedy in such cases

Waters frequently contain considerable amounts of dissolved gases, mostly carbon dioxide, and sometimes in the case of underground waters, hydrogen sulphide. Carbon dioxide imparts a rather pleasant taste but in considerable amounts, owing to its solvent qualities, may be accompanied by increased quantities of other minerals such as iron or manganese. If present in the free state, carbon dioxide will attack iron pipes and containers and cause serious trouble in distribution systems. Hydrogen sulphide imparts a disagreeable odor and taste. Oxygen and nitrogen are normally present in all surface waters and to a lesser extent in ground waters, and have a beneficial effect, especially the former.

PHYSICAL CHARACTERISTICS.

In addition to the above factors affecting quality, there is another group which, while not directly harmful to health, must yet be considered. Their presence in water may be said to offend the aesthetic senses and in that way divert consumers to the use of even unsafe sources of supply in which these factors are absent. Such factors are color, odor, taste, turbidity, and temperature.

Color in water is usually of organic origin and of a complex chemical composition little understood. Compounds of iron are sometimes responsible for mineral coloring in water. Vegetable color usually originates from water that has been in contact with swampy areas, dead leaves and vegetation, peat, etc., and varies in intensity at dif-

ferent seasons of the year, depending on the length of contact. Many New England surface waters are highly colored and have the appearance of weak tea (the "meadow tea" of Thoreau). Color can be removed by chemical treatment and filtration and to a certain extent by storage and exposure to sunlight.

Odor and taste are closely allied, both conditions usually being present in the same water. Odor in water may be caused by vegetable matter, microscopic organisms, or chemicals in solution. Many waters that are highly colored have a distinct odor of humus or musty wood, derived from the vegetable matter with which they have been in contact. Microscopic organisms are a prolific source of a variety of odors, many of which are highly objectionable. Such odors are caused by oily substances generated by certain growing organisms and hence vary with the concentration of these organisms at different seasons of the year. They are most noticeable in stored waters exposed to light and air. These organisms on decaying give rise to still other kinds of odors and tastes that are mostly disagreeable. Certain chemicals may also produce marked tastes and odors, such as the paint of new water pipes or waste coal-tar derivatives from gas works and allied industries. Excessive dosage of water with chlorine gas or hypochlorite of lime also produces marked tastes at times.

Turbidity of water is caused by opaque substances held either in suspension or colloidal solution. Turbidity may be caused by clay, silt, iron, microorganisms, organic matter, etc., and is generally more pronounced in surface waters. Underground waters as a rule are clear, with little or no turbidity. Excessive turbidity is most common in waters draining from clay soils and settles out more slowly when in this form. Turbidity can be reduced by sedimentation and storage and can be entirely removed by coagulation with chemicals, followed by filtration.

Temperature of water is of necesssity a varying factor, depending on season, latitude, and source. The temperature of surface waters fluctuates between much wider limits than that of ground waters, and for this reason the latter are generally preferred, if available, especially in warmer climates. Whipple states (1, p. 28) that when the temperature of water exceeds 60° F. it becomes unpleasant for drinking, and he further assumes that half the consumers would object to a temperature exceeding 66°, and all would object to a temperature of over 75° F. Another result of higher temperatures is an increase of microscopic organisms and plant life, with the consequent probability of increased tastes and odors.

Possibility of Pollution.

The potential dangers and possibilities of pollution of any source of water supply should be thoroughly investigated and analyzed because of the direct bearing this group of factors has on the develop-

ment of the source. Any community is usually limited to a comparatively few available sources of water supply, and the selection of any source must take into consideration the factors enumerated under this head, if not from the standpoint of acceptance or rejection, then from the standpoint of nature and degree of treatment necessary to counteract the effects of such pollution factors as are found to exist. Some of the factors requiring consideration under this head are geological formations of the area, surface scour and wash, vegetable and animal growths, and contamination by human agencies.

The geological formation of any area has much to do with the possibilities of pollution of water supplies. A tight clay soil offers much less probability of wastes from a pit privy percolating to a near-by well than would a coarse gravel stratum. Fine, porous, sandy soils also act as natural filters and reduce the potential danger of pollution. On the other hand, cavernous limestone regions containing free underground channels where polluting wastes may be carried for long distances are highly dangerous. In fact the sewage from some cities in such regions is sometimes discharged into sinks with unknown outlets. Many instances are on record where peculiar geological formations have been the direct cause of serious epidemics of water-borne diseases.

Knowledge of the geological formation is also of value from the standpoint of mineral pollution of possible water-supply sources. Thus the underground waters of certain areas are strongly impregnated with sulphur, rendering such waters useless as sources of supply; other areas produce only highly saline waters, and still others have an abnormally high iron content. Even surface waters may be seriously affected by contamination with highly acid drainage from active or abandoned coal mines, or may be liable to be so contaminated if coal measures form a part of the geological strata.

Surface wash also plays a part as an active or potential source of pollution. High turbidities are mostly the effect of excessive surface scour, which brings to the stream a conglomerate mixture of polluting substances, including dangerous and offensive organic matter deposited on the watershed. Usually such pollution is highest at periods of high-stream flow, regardless of the increased dilution at such times. Flashy, quick-spilling streams with wide and sudden variations in discharge need, therefore, to be carefully examined when considered as sources of supply. Forestation is usually conceded to have a deterrent action on soil erosion, and is therefore of value in the protection of watersheds, hence in the reduction of turbidity of streams.

Vegetable and organic growths also play a part in the possible pollution of water supplies. Water coming from some sources may

be so heavily seeded with vegetable organisms at times as to render it almost unfit for use by imparting disagreeable tastes and odors. Water from pine forests and peat swamps may be highly colored and have tastes that render it very objectionable. Certain microorganisms will also have a serious effect on tastes and odors if the source is not properly protected or if proper care is not exercised in storage and handling of certain classes of supplies. While these matters may not be regarded as polluting in the strict sense of the word, they are certainly factors that influence the use and popularity of the supply.

Pollution by human agencies is the greatest and most serious source of potential and actual contamination of water supply. The ways in which such pollution may reach a source of water supply are almost infinite. The only safe way to eliminate the possibility of such pollution is to remove the cause—that is, all human contact, both direct and indirect, with the source. Just in so far as this is done will the potential danger be reduced in degree. Attempts to follow this course have been made by many communities, notably those having untreated surface supplies. The watersheds have been entirely depopulated, many of them reforested, and are being carefully patrolled to prevent even accidental pollution. The results obtained by these measures have justified them. Other communities have for various reasons not been able to inaugurate such complete measures or have found other safeguards better adapted to particular conditions. There is practically, however, no unused surface source of supply of any size in this country that is not in potential, if not actual, danger of pollution by human agencies; and any contemplated source of this nature should be provided with suitable machinery for its protection or the elimination of the pollution before being used for drinking water. Where pollution of the source is of such nature as to be impractical of prevention, then measures for removal of this pollution by some artificial-treatment process must be provided to safeguard the consumers.

Natural Safeguards.

The detrimental effects of various agencies, both natural and artificial, on the quality of water supplies have been indicated above. In the grand balance of forces which nature attempts to maintain there is another set of factors actively engaged in reducing these detrimental effects—natural safeguards that are of immense value in assisting to restore such polluted water to its original quality. Some of the most important of these safeguards that may be employed are forestation, natural filtration, aeration, impounding or storage, and plankton activity.

Forestation of extensive areas has a considerable retarding effect on the extent of the soil erosion and thus diminishes the amount of

silt and clay reaching the watercourse. Moreover, the humus top layer of soil developed acts as a filter and natural storage medium for water falling on it and may thus tend to regulate stream flow. The effect of forests on flood prevention is a much controverted question. Forestation properly maintained on any watershed does, however, suppress the increase of human population in such areas and thus tends to hold in check the potential or actual dangers of human pollution. If rigidly enforced, such forestation may eliminate all resident population and thus greatly reduce the probability of dangerous pollution.

Natural filtration is a safeguard of great value in the purification of water. The continuous action of this agency is well illustrated in the low bacterial content and turbidity of ground waters; hence their popularity for drinking-water supplies. The extent of filtration depends largely on the nature of the filtering medium or geological composition of the soil. Fine sandy soils, being more porous, filter and retain larger quantities of water than closely compacted ones, and hence are more efficient in this respect. Clay and closely compacted soils, while excellent filters, allow such small volumes of water to pass that they are deficient from the standpoint of quantity; the greater part of the rain falling on them is shed as surface water.

The process of natural filtration is rather complex and makes use of various agencies for effecting the result. There is first of all a straining action by which larger particles, and some smaller ones as well, are prevented from passing through the filtering layers with the water. In addition there is a great reduction of velocity of the liquid which causes deposition of suspended matter and, by increasing the time of flow, permits the death of organisms to proceed within the filtering medium. Moreover, the grains of the filtering material finely divide the water passing through, and thus facilitate the oxidation of impurities by means of the oyxgen carried in solution in the water. Filtration is therefore a combination of mechanical, biological, and chemical processes.

Aeration is a natural safeguard that is most active in self-purification processes. The benefits are those caused by bringing the oxygen contained in the air into intimate contact with the impurities in the water, and thus hastening the oxidation of unstable compounds by providing ample supplies of oxygen for the biochemical reactions taking place. Since oxygen is being continuously absorbed by water surfaces for this purpose, the extension of exposed water surface facilitates aeration. This extension may be effected by waterfalls, riffles, or turbulence caused by irregularities in stream channels, or even by artificial devices. Aeration may at times have a certain mechanical effect by releasing gases that are held in solution and that impart odors and tastes, such as hydrogen sulphide or sulphur dioxide. Ex-

cessive carbon dioxide content of underground waters may also be released by aeration.

Impounding or storage of water affords a means for a certain amount of natural purification by facilitating sedimentation of impurities. Finely divided suspended matter, as well as some bacteria that will not settle in moving streams, will be dropped to a large extent where the velocity is sufficiently reduced. Storage also may permit the action of light to bleach and reduce color. Storage also provides time and generally suitable environment for the activities of bacteria-consuming organisms and biochemical reactions that have a beneficial effect upon quality.

Another important factor in self-purification, acting as a natural safeguard, is the extensive variety of microscopic living forms that move about in the water and are commonly known as plankton. Plankton are of two general types—one being food producers which convert inorganic matter into organic compounds, and the other, food consumers or animals which feed on the bacterial flora. The complete significance of plankton life and activity is not understood. However, some of the plant forms liberate oxygen from certain compounds and make it available for oxidation of organic matter in the water. The animal forms, by feeding on the bacterial content, enormously increase the normal death rate of all bacteria in the water, pathogenic forms as well as others, and thus have a distinct bearing on self-purification. This class of plankton is most numerous where its food supply is most plentiful, and hence fluctuates in number with the bacterial content with which it comes in contact.

Cost.

A primary factor in the selection of a source of water supply, and, in fact, often the governing one, is that of cost. Regardless of many other considerations, cost must always be taken into account and will at once rule out, in many cases, otherwise satisfactory sources. Costs should be carefully analyzed for any project and each item should be given its proper weight, especially in those instances where certain factors tend to offset the first cost of apparently more expensive systems considered from the standpoint of installation alone. Thus it might be cheaper to expend considerably more money to secure a naturally soft water than to install a cheaper hard-water supply and then pay for excessive soap waste and increased expense incurred by industrial users.

The factor of cost will also determine whether it is advisable to neglect largely the factors of existing pollution in a source and provide for the artificial purification of the water before use, rather than attempt to eliminate such sources of pollution or seek a source where

such pollution does not exist. Because of the scarcity of naturally pure sources of supply and the prohibitive cost of making such sources satisfactory, various means have been developed for artificially purifying water. A careful analysis of costs will determine just which device or combination of devices should be used for securing a satisfactory supply in any individual case. Cost is therefore a factor that will usually have great weight in the selection of a source.

Summary.

The selection of a source of water supply depends on a number of factors, all of which should be given due consideration and weight before a choice is made.

Determination of the nature and extent of use of the proposed supply will at once indicate the inadvisability of selecting certain inadequate or unsuitable sources. Such determinations will also make evident the necessity for accurate knowledge concerning the quantity and quality of water to be expected from various sources.

The possibility of pollution of the source is also a factor to be carefully considered, as well as the natural safeguards that exist or can be inaugurated that tend to counteract such pollution.

Finally, the relative cost of supplies developed from various sources, carefully balanced against their advantages, will determine largely the source to be chosen. This factor may outweigh many other considerations and indicate the advisability of artificial purification rather than the selection of an uncontaminated source.

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(*e*) Canadian Engineer, Toronto, Ont.
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(*h*) The Surveyor and Municipal and County Engineer, London, Eng.
(*i*) Transactions American Society Civil Engineers, New York.
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(*m*) Journal, Association of Engineering Societies, Philadelphia, Pa.
(*n*) Proceedings, American Water Works Association, Troy, N. Y.
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(*u*) Journal of Electricity, Power, and Gas, San Francisco, Calif.
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